Lifetime limiting effects in pre-commercial solid oxide cell devices - DTU Orbit (07/12/2018)

Lifetime limiting effects in pre-commercial solid oxide cell devices
The solidoxide electrochemical cell technology is promising for efficient energy storage, especially when the share of intermittent renewable electricity production is high. The technology is being commercialized in niche markets, but large-scale employment is still hindered by limited durability of the devices. The lifetime limiting mechanisms are addressed in this work.

A general introduction into mechanisms limiting the durability is presented. A database of more than 50 parameters from 150 publications and 1,000,000 hours of accumulated testing was established, and a quantitative analysis of degradation and lifetime was conducted. It is shown that the technology is approaching the official targets required for commercialization, but that work remains to be done.

It is further recognized that targeting niche applications initially will allow for employment of economies of scale, which will bring down costs and facilitate entry into larger markets. Here, we examine electrochemical reduction of CO₂ to CO and one of the main failure mechanisms related to it. Carbon formation on the nickel electrocatalyst can be detrimental to the microstructural integrity of the cell. It is found that the possible operating window is severely limited due to gradients of temperature, gas concentration and overpotential across the electrode. These affects also apply to stack- and system-level, and the results obtained are combined with modeling and stack testing experiences. Thus, on account of this mechanism, the possible outlet CO concentration is limited by up to 50% below the thermodynamic carbon deposition threshold based on the inlet temperature, depending on design and operating strategy.

Replacement of the Ni electrocatalyst would increase the stability towards this issue and may improve the robustness in other ways as well. Ceria has been reported as a potential candidate in such endeavors. Thin film electrodes of nickel and ceria are therefore studied as model systems using near-ambient pressure x-ray photoelectron spectroscopy to further the fundamental understanding of the carbon formation mechanism. The reaction occurs further from the thermodynamic threshold on ceria, and fundamental mechanisms for electrochemically driven carbon growth are suggested based on observed adsorbate species.

By infiltrating ceria after degradation has already occurred, the robustness and lifetime of the cells are increased. Complete reactivation of the fuel electrode is achieved after otherwise detrimental failure mechanisms have occurred, such as reactant starvation and carbon formation. Moreover, the degradation of the electrode over the course of nearly 2500 hours is essentially eliminated by infiltrating after microstructural stabilization had occurred. Lastly, the method is scaled up by replicating the positive effects of post-degradation infiltration on an 8-cell stack.

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